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Adult Foot and Ankle Trauma at Schroeder Mounds (11He177): A Late Woodland Period Site in Illinois

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Adult Foot and Ankle Trauma at Schroeder Mounds (11He177): A Late Woodland Period Site in Illinois

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Abstract: Foot and ankle trauma in adults may be accidental or caused by physical activities that increase the likelihood of injury. Little is known about the organization of labor or health of the presumed forager-farmers of the later Late Woodland (~AD 900-1150) period mortuary site of Schroeder Mounds (Henderson County, Illinois). In order to better understand the physical activities or hazards of the individuals from this site, thirty-seven adult skeletons preserving at least one essentially complete mid (metatarsals) and hind (tarsals) foot were examined for reactive changes that are consistent with traumatic injury. This data is compared to published reports from other Illinois Late Woodland sites. The study is comprised of 17 females, 14 males, and 6 skeletally unsexable adults. In the Schroeder Mounds sample, there were six cases of foot/ankle pathology (6/37, 13.5%), five of which (3/17, 17.6% females; 2/14, 14.3% males) are diagnostically traumatic injuries (5/37, 13.5%). A sixth case is a likely congenital foreshortening of a metatarsal (brachymetatarsia). There is no significant difference between the sexes in the frequency of ankle/foot trauma (p=1.000, Fisher's test). However, given the small sample size, the results are tentative. The trauma pattern of the Schroeder mounds cases consists of the clinically infrequent tarsometatarsal (Lisfranc joint complex) high-energy misstep injuries, a vertical jump/fall (Pilon fracture), and stress ("march") fractures of the metatarsal shafts. These injuries are consistent with a highly active and/or mobile community where trauma hazards are arguably equally experienced by both adult males and females.

Keywords: Adults, Late Woodland Period, Schroeder Mounds, Foot, Ankle, Trauma

Introduction

Trauma to the foot or ankle can be clinically characterized as moderate or severe based on the cause of the injury. For example, if it involves a fall from a height, it is considered severe; if it is a result of slipping on solid ground, it is deemed moderate (Daly et al. 1987; Rich et al. 2005; Steckel

2003, 2004). Without proper treatment, individuals who have sustained traumatic injuries to the foot and/or ankle usually experience some level of permanent functional impairment (Hansen 2000; Hatch et al. 2007; Thordarson 2004). In affluent societies, there is the option of surgical intervention or biomechanically supportive foot/ankle casts, progressive knee splints, scooters, scooter/walkers, etc. (Green and Swiontkowski 2009; Hansen 2000; Rich et al. 2005; Thordarson 2004).

However, for those who are unable to obtain long-term treatment or convalescence, there are a myriad of biomechanical problems that are consequential to foot/ankle injuries (e.g., Greene and Wight 1990; McLain 1991; Steckel 2003, 2004; Wikstrom et al. 2009). This is less problematic for subadults because healing time is shorter, and there is less fear of physical deformities, joint disease, and infection (Beynnon et al. 2001; Green and Swiontkowski 2009; McLain 1991; Nelson et al. 2007). This is partly due to the growth and development of children, whereas adult bodies have ceased growing and require prolonged treatment for traumatic injuries that the body may sustain (Beynnon et al. 2001; Green and Swiontkowski 2009; Thordarsen 2004).

The main cause of traumatic foot/ankle injuries are accidental and usually occur when an individual has fallen from a substantial height (Daly et al. 1987; Green and Swiontkowski 2009; Greene and Wight 1990; Hansen 2000; Steckel 2003, 2004; Thordarson 2004). However, traumatic injury can also occur from a misstep or the drop of a heavy object on the foot. The pattern of injury depends on the severity of the injury. However, direction of the impact to the foot/ankle (e.g., vertical, lateral, twisting) and the degree of the impact (e.g., low or high energy, chronic microtrauma from overuse [marching or jogging]) are also factors. In archeologically-based adult samples without any material culture data about community labor, subsistence, and other environmental trends, activity patterns are difficult to infer. By assessing the pattern of injury to the foot/ankle from clinical data and analogous trauma data from other archaeological contexts (i.e., Alabama Archaic period Perry [1Lu25], Late Woodland 1Pi61, Mississippian period Moundville [1Tu500] and Koger Island [70Lu92] sites), it may be possible to deduce the kinds of actions or activities engaged in by the Schroeder Mounds community.

The Late Woodland Period in Illinois (~AD 650-1000) was a time of substantial subsistence, settlement, demographic (i.e., population increase), and sociopolitical change (Emerson et al. 2000; Scarry 1993; Steckel 2004; Stoltman 2000; Studenmund 2000). The trajectory included increased dependence on agriculture and more permanent settlement. Some of the signature features of the subsequent Mississippian period (~AD 1050-1350), such as village aggregation and political centralization, appeared. However, this process was not linear and varied geographically in the rate and degree of change. Little of this trajectory is known for west-central Illinois. The Schroeder Mounds site (Figure 1) is a later Late Woodland (~AD 900-1150) burial context from west-central Illinois that is located on a bluff line in the Mississippi River Valley of Henderson County, Illinois.

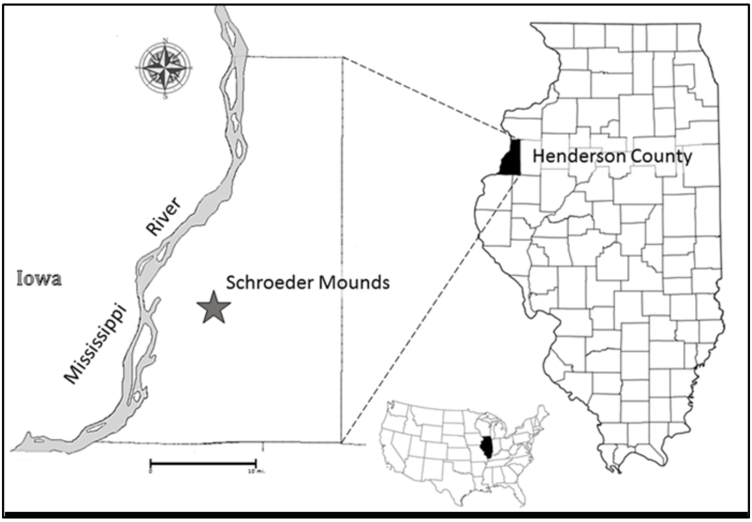

Figure 1: The location of the Schroeder Mounds mortuary site (starred) in the Mississippi River Valley of Henderson County, west-central Illinois.

There is no associated village site, so there are no archaeological data to indicate subsistence or settlement pattern (Kolb 2000; Riggle 1981). However, bioarchaeological analysis has inferred sedentism (Mosher et al. 2015) and dietary dependence on maize (Lacey and Smith 2013). Recent skeletal analysis has provided better insight into the lives of these Late Woodland period individuals (e.g., Neidich and Smith 2016; Nicosia et al. 2016; Smith et al. 2016).

The purpose of this study is to determine the prevalence and patterns of foot/ankle trauma within the Schroeder Mounds adult sample. The prevalence and pattern of these injuries could suggest terrain, division of labor by sex, and the intensity of the labors undertaken by forager-farmers. The gathered information may provide a better understanding of the environmental and cultural challenges of the Schroeder Mound adults.

Materials and Methods

The Schroeder Mounds Sample

Out of an estimated one hundred and twenty-three individuals recovered from the Schroeder Mound site, there are approximately fifty-six adults (Smith et al., 2016). To be included in this study, individuals had to preserve at least one distal tibia and fibula (i.e., a tibiotalar joint) and/or seven tarsals and five metatarsals (i.e., the equivalent of the bones of at least one foot). To be considered as an observable skeletal element, at least one articular surface had to be present. The individuals from Schroeder Mounds were previously aged and sexed (Mosher et al. 2015; Smith et al. 2016) using the criteria outlined by Buikstra and Ubelaker (1994). Thirty-seven Schroeder Mounds adults, defined as minimally exhibiting two maxillary or mandibular third molars in occlusion, are complete enough to be used in this study. The Fisher's Exact Test was used to assess the sex differences in foot/ankle trauma. Significant difference was set at the 95 percent confidence level ($P= \leq 0.05$). This test was chosen because it best considers the error factor of small sample sizes, such as that of Schroeder Mounds.

Quantifying Foot and Ankle Trauma

The talocrural (i.e., ankle) joint surfaces of the tibia and fibula and the shafts, the areas of ligament insertion, and joint surfaces and margins of the tarsals, metatarsals, and phalanges were examined for reactive changes consistent with mechanical injury. These changes include periostosis (e.g., fracture callous), entheseal reactive changes at the insertions of ligaments, osteophytosis along joint margins, joint surface pitting and/or eburnation, and reduction in length or shaft misalignment (as compared to a laboratory specimen) (Parfitt and Chir 1987; Schindeler et al. 2008; Wexler 1998; White et al. 2011). Traumatic injury is distinguished from degenerative changes by comparing the reactive change observed on the pedal bones against clinical orthopedic descriptions of ankle/foot trauma. These include identifying the ankle injuries of Pilon or Plafond (i.e., compression or axial) fractures of the distal tibia (Dujardin et al. 2014; Mandi et al. 2012), talar dome injuries (e.g., osteochondral lesions) (Schachter et al. 2005; Yvars 1976), and articular and body trauma of the calcaneus (Bajammal et al. 2005).

It also includes detecting tarsometatarsal (i.e., Lisfranc joint complex) injuries (Gotha et al. 2013; Gupta et al. 2008), midshaft fractures of the metatarsals ('march' fractures) (Giuliani et al. 2011) as well as stubbing injuries of the metatarsophalangeal and/or interphalangeal joints (Coker et al. 1978; Jahss 1981).

Significance of Age on Trauma Injuries

Age can play an important role when analyzing foot/ankle trauma (Daly et al. 1987; Green and Swiontkowksi 2003; Rich et al. 2005; Thordarson 2004). With an increase in age, there may also an increase in the severity of foot/ankle injuries (Browner et al. 2009; Daly et al. 1987; Rich et al. 2005). This may be attributed to frailty in advancing years, and/or the physical expectations of experienced and mature laborers. When looking at trauma sustained in the foot/ankle of adults, it is important to analyze whether the bone had healed or was healing properly at the time of death. If this area did not heal properly, it could have cascading adverse biomechanical effects for the individual who sustained the injury (Agnew and Justus 2014; Hansen 2000; Hatch et al. 2007; Thordarson 2004).

Results

Five out of thirty-seven individuals (13.5%) show signs of foot or ankle pathological change consistent with trauma, and one individual exhibited metatarsal foreshortening (Table 1). Approximately 14.3% of adult males (2/14) and 17.6% of females (3/17) exhibited trauma. A Fisher's Exact test indicates that there is no sex difference in the prevalence of foot/ankle trauma (p=1.0000). The most common pedal bones to sustain mechanical injury are the metatarsals. Only one individual exhibits reactive change at the talocrural joint. Three cases with foot/ankle trauma fall within the skeletal-age-at-death of 25-35 years. Two individuals were over 50 years of age at death.

Based on the raw frequencies of foot/ankle trauma from several sites from Alabama (Bridges et al., 2000), the Schroeder Mounds total site frequency (13.5%) is statistically (Fisher's Exact test) significantly higher than the Archaic period (2500-100 BC) Perry site (2/94, p=0.00191) and lower than the Mississippian (AD 1200-1500) sample from Moundville (11/564, p=0.0018). Were it not for the similar case frequency with the Mississippian period Koger Island sample (8/108, p=0.3174), the Schroeder sample's frequency similarity to the Late Woodland IPi6I site (8/96, p=0.3368) might suggest a subsistence/settlement pattern.

Table 1: Foot/Ankle bones showing signs of pathologic change within the Schroeder Mounds sample.

Burial	Age at Death	Tarsals	Metatarsals	Phalanges	Tibia	Fibula
2	25-25 years		L. M3-M4			
26	65+ years	L. cuboid L. lateral cuneiform R. cuboid R. lateral cuneiform	L. M1-M5 R. M1-M5			
39	25-35 years	L. navicular R. medial cuneiform R. navicular R. intermediate cuneiform	L. M1, M4 R. M4			
46	25-30 years	L. intermediate cuneiform L. lateral cuneiform L. talus L. calcaneus	L. M1-M4		L. tibia	L. fibula
48	50+ years	L. cuboid L. lateral cuneiform L. intermediate cuneiform L. navicular L. calcaneus R. navicular R. medial cuneiform R. intermediate cuneiform R. calcaneus	L. M1-M5 R. M1-M5	L. proximal phalanx(M1) R. proximal phalanx(M1)		
115	25-35 years		L. M4 R. M4			

Burial 2

The pedal bones present in this mature adult female consist of all seven of the left and the right tarsals, both complete tibiotalar joints, and all five of the left and the right metatarsals. Additionally, all five of the proximal phalanges, the left distal hallux, the left and right fourth medial phalange, the right second medial phalanx, an unsideable fifth medial phalanx, and five unidentifiable distal phalanges are preserved. Reactive change on the pedal bones of Burial 2 is confined to the left foot (Table 1). The change consists of lipping on the abutting surfaces of M3 and M4 (Figure 2, Burial 2a) and an expansive periostosis of the body along the lateral surface of M4. There is no evidence of misalignment of either metatarsal. There are no reactive changes on the cuboid, which articulates with the proximal margin of M4 or the lateral cuneiform, which in turn articulates with the M3. The traumatic injury is consistent with a tear of the interosseous ligament, which would occur in an injury that forced a lateral displacement of M3 and/or M4 (Figure 2, Burial 2b). The reactive changes are consistent with a divergent form of the Lisfranc injury of the midfoot (Desmond and Chou 2006; Gupta et al. 2008).

Burial 26

All left and right tarsals, metatarsals, and proximal phalanges are present in this adult female (Figure 2, Burial 26a). The only medial phalanges present are those of a left and right second or third toe. The only distal phalanges present belong to the hallux. Burial 26 exhibits traumatic injury to both feet at the tarsometatarsal joints (Table 1). Reactive changes on the proximal shafts of the left M2-M4 with joint surface osteoarthritis (porosity) restricted to M4 (Figure 2, Burial 26b, 26c). There is lipping on the metatarsal shafts between M4 and M5 and extensive lipping on the medial surface of M2. The fifth metatarsal exhibits an avulsion fracture that resulted in a pseudarthrosis (false joint) of the tip of the tuberosity. There is nodular osteophytic lipping on the dorsal surface of the tarsometatarsal joint perimeters of M2, M3, and M4. There is a small discrete area of osteoarthrotic pitting on the medial plantar surface of the M1. There is slight nodular pitting of the cuboid on the dorsal surface of the articulation with M5. The lateral cuneiform (Figure 2, Burial 26d) exhibits osteoarthrotic pitting on the surface of the tarsometatarsal joint as well as exuberant osteophytic overgrowth of the dorsal joint margin.

The reactive changes on the right foot mirrors those observed on the left. The M1 exhibits the most reactive change. It consists of lipping on the medial surface of the proximal end, and osteophytic nodules on the dorsal joint perimeter. There is intermetatarsal lipping between M4 (Figure 2, Burial 26b) and M5 at the proximal ends of each bone and the medial surface of the proximal end of M2 (Figure 2, Burial 26c). No tarsometatarsal joint surface exhibits porotic damage, but the dorsal joint perimeter of the cuboid exhibits slight nodular osteophytosis.

The articulation of the M3 (Figure 2, Burial 26b) with the lateral cuneiform suggests the bone had a medial angle. Essentially, the injury consists of damage to the tarsometatarsal joint of M2, M3 and the cuneiform and the proximal end of M2, with the consequence of the medial displacement of M3. The pattern injury on both the left and right foot is consistent with an isolated and/or divergent form(s) of the Lisfranc injury (Desmond and Chou 2006; Gupta et al. 2008).

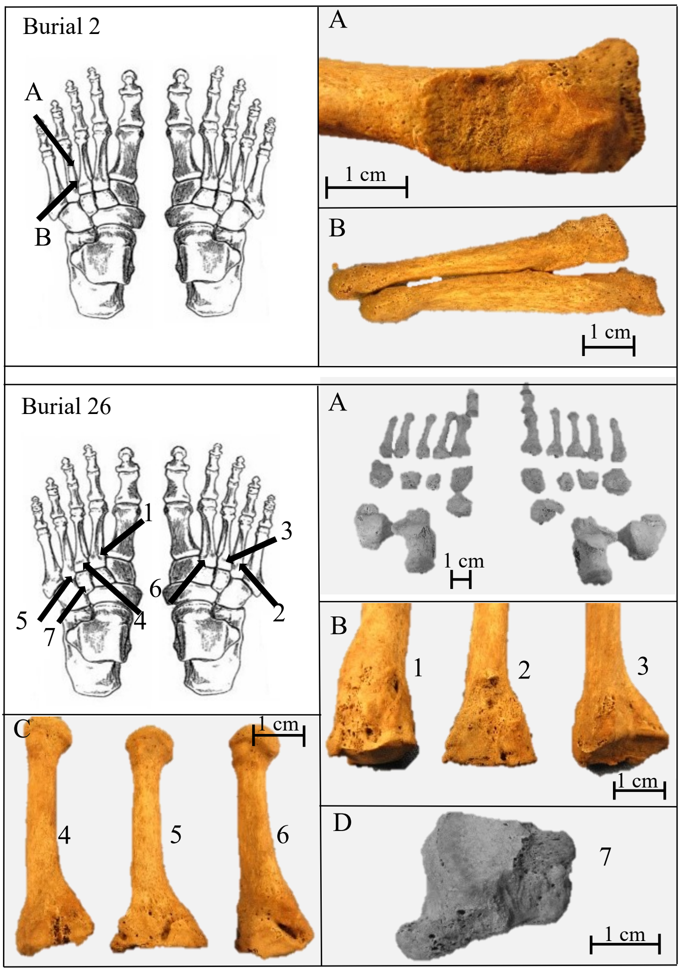

Figure 2: Examples from Burial 2 A) lipping on the medial surface of M3, B) lateral displacement of M3 and M4; and Burial 26 A) tarsals, metatarsals, and phalanges, B) reactive change of the left M2, right M4 with intermetatarsal lipping, and right M3 tarsometatarsal damage, C) reactive change to left M3, osteoarthritis restricted to left M4, and lipping on medial and proximal end of right M2, D) left lateral cuneiform showing osteoarthritic pitting.

Burial 39

All metatarsals, and all tarsals except for the left medial cuneiform, are present in this adult male. The medial and distal phalanges of both halluces are present. Four additional proximal phalanges are preserved. Based on size and symmetry, there is a left and a right fifth phalanx. A larger phalanx exhibits a healed compression fracture that affected both joint surfaces (i.e., osteophytic remodeling). It articulates with the proximal joint of a medial phalanx that is fused with a distal phalanx. Given that the fourth metatarsal of the right foot exhibits reactive change and is markedly shorter than the left, it is likely that the phalanges belong to a right fourth phalanx. The comparative size of the remaining proximal phalanx indicates that it is medial to the other three, but is unsideable. The only other medial phalanxarticulates with it. Additionally, there are three unidentifiable distal pedal phalanges.

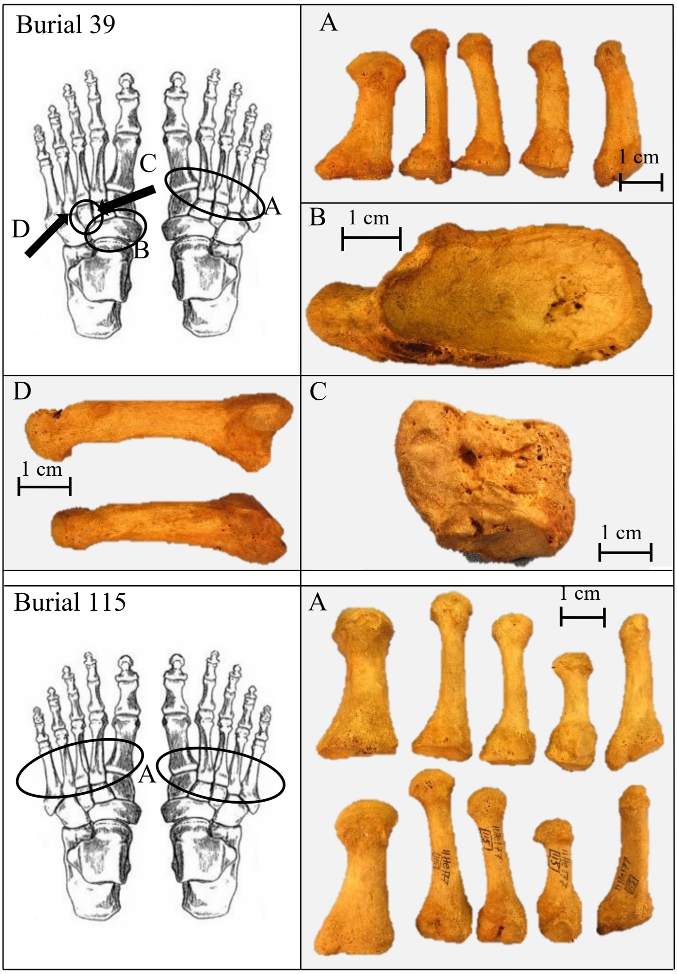

Figure 3: Examples from Burial 39 A) Expanded body to the right M4, with no reactive change to the proximal or distal end of the metatarsals B) reactive change on the navicular at the talar articulation, C) damage to the joint surface of the right medial cuneiform, D) periosteal reactive change to the tarsometatarsal joint at M4-M5; and Burial 115 A) evidence of brachymetatarsia on the fourth (from the left) metatarsal.

The right M4 is eight millimeters shorter than the left and has an expanded body due to periostotic remodeling. There is no reactive change on either the proximal or the distal joint surfaces (Figure 3, Burial 39a). None of the other metatarsals exhibits reactive change on a body or joint surface. The only tarsal to exhibit reactive change is the medial cuneiform. The change consists of damage to the joint surfaces (Figure 3, Burial 39c) (healed fracture line, osteophytic lipping, and large pore [macro] pitting) that articulate with the navicular and intermediate cuneiform.

The left foot exhibits a similar suite of reactive change. The left M1 is three millimeters shorter than the right and has an expanded body due to periostotic remodeling. Neither the proximal nor the distal joint surfaces exhibit reactive change. The M4, although larger and presumably reflecting the undamaged phalangeal length exhibits periosteal reaction on the medial and pedal surfaces and a non-inflammatory node on the lateral surface. Although the left medial cuneiform is not present, the only tarsal to exhibit reactive change is the navicular (Figure 3, Burial 39b).

The joint surface that articulates with the tarsal (i.e., the talonavicular) exhibits hypertrophied margins, depressions in the outer margins of the concave joint surface, and a necrotic focus, possibly osteochondritis dissecans (Beil et al. 2012; Bui-Mansfield et al. 2000). The tarsal bone is unaffected. The patterns of reactive change on both feet suggest the consequence of a high energy axial force (e.g., stubbing trauma) (Pinckney et al., 1981).

Burial 115

All five metatarsals and seven tarsal bones, along with all the proximal phalanges of the right and left foot are present on this adult female. The left foot preserves the distal phalanx of the M1, as well as a possible M2 distal phalanx. The right foot preserves the distal phalanx of the M1. There is no reactive change to any of the joint surfaces or joint margins. However, the M4 of both the right and left foot show a fifteen to twenty-two-millimeter foreshortening of the body relative to the adjacent metatarsals (Figure 3, Burial 115a). Additionally, there is hypertrophy of both the tarsometatarsal joints of the M4. The absence of any traumatic or inflammatory reactive change suggests that Burial 115 is a case of M4 brachymetatarsia, a probable congenital condition (Ferrandez et al. 1993; Handelman et al. 1986; Robinson and Ouzounian 1998; Schimizzi and Brage 2005).

Burial 46

Most of the preserved pedal bones from this male individual belong to the left foot (Table 1; Figure 4, Burial 46a). It preserves the talocrural joint, all five metatarsals and all seven tarsals, including a very fragmentary navicular. The left foot also preserves one of two proximal phalanges, both of which belong to the hallux. The only distal phalanxis the left hallux. The right foot preserves only the M2 and M3, the navicular, a fragmentary M1, and the other proximal phalanxof the hallux. There are no bones of the talocrural joint. The bones of the right foot that are preserved exhibit no pathologies.

There is extensive reactive change on the bones comprising the left talocrural (i.e., ankle) joint. The distal metaphysis of the fibula is misaligned and the joint margin exhibits extensive osteophytic remodeling. There is no pitting on the joint surface, but the contour is uneven and nodular. The distal tibial joint perimeter also exhibits osteophytic remodeling. The joint surface exhibits an uneven contour, a discrete area of porotic pitting, and grooving along the margins suggesting a pan-caking of the joint surface (i.e., talar dome injury).

The trochlea of the talus has a much-altered joint margin with large areas of osteoarthrotic damage (Figure 3, Burial 46c). The trochlea also appears to be flattened, as there is virtually no neck to the talar body.

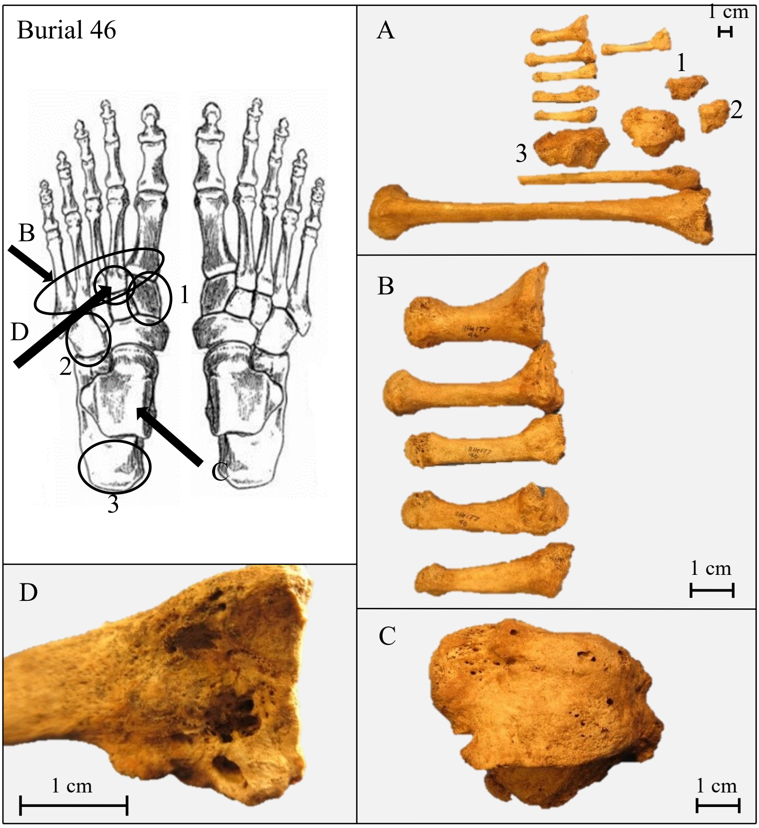

Figure 4: Examples from Burial 46 A) the preserved left cuboid, medial cuneiform, calcaneus, talus, tibia, fibula, metatarsals, and one right metatarsal, B) left metatarsals with remodeling to the proximal joints, C) left talus with severe osteoarthrotic damage, D) left second metatarsal with extensive proximal joint remodeling.

There is no alteration of the head of the talus (talonavicular joint) or the anterior calcaneal articular surface, but the posterior calcaneal articular surface has extensive remodeling of the lateral margins of the joint with joint surface osteoarthrotic pitting. Conversely, the anterior talar joint of the calcaneus exhibits remodeling consisting of joint surface pitting and osteophytic overgrowth at the joint perimeter.

There is no reactive change on the distal joint surfaces of the metatarsals, but there is extensive remodeling of the proximal joints of M1 through medial M4 (Figure 4, Burial 46b, 46d). The cuboid, which articulates with M5 and M4, does not exhibit any reactive change. There is osteophytic compressive damage to the joint surfaces of M3/M4 and M2/M3.

There is corresponding osteoarthrotic damage to the tarsometatarsal joints and dorsal joint perimeters of the intermediate and lateral cuneiforms, but not to the medial cuneiform. However, there is some lipping of the proximal M1 on the plantar surface of the perimeter. The reactive changes are consistent with a low or high-energy landing from a height (Mandi et al. 2012) on, at least, the left ankle (Pilon) and mid-foot foot (Lisfranc).

Burial 48

Burial 48, an adult female, displays acute traumatic injury on both feet. Neither tibia nor fibula preserve, but all the tarsals, metatarsals, and both proximal phalanges of the hallux, are preserved (Figure 5, Burial 48a). Four, but possibly five, additional unsideable proximal phalanges are present. Except for the distal right hallux, there are no medial or distal phalanges present.

Neither calcaneus shows any reactive change to the articular surfaces, but there is osteophytic reactive change at the insertion of the Achilles tendon. Neither the tali, nor the naviculars, exhibit any reactive changes to the joint surfaces, but there is trace osteophytic lipping on the dorsal surfaces of both naviculars along the dorsal margins of the articulations with the cuneiform bones. The primary reactive change occurs on the metatarsals of both feet with minimum damage to the tarsal bones.

On the right foot, the M1-M4 exhibit varying degrees of joint and/or body destructive reactive change. M1 has osteoarthrotic reactive change on the joint surface margin of the distal joint surface. The proximal joint is unaffected, but the medial surface of the proximal end has a pressure facet where it is in contact with M2 (Figure 5, Burial 48c). The second metatarsal has a large area of reactive bone growth at mid body along the intermetatarsal border of M2-M3 that has healed as one side of a pseudarthrosis to a much-damaged M3. The M3 exists as two fragments (Figure 5, Burial 48b); it is a proximal end with minimal tarsometatarsal joint damage and a pseudarthrosis with the distal end of the body that preserves as a fused mass along its border with M4. The distal joint is compressed with joint remodeling suggesting a deformed or remodeled proximal phalange. The kidney-bean shape of this remodeled joint surface fits one of the four preserved proximal phalanges. If this articulation is correct, the phalanxof this much-altered right M3 has an undamaged medial phalange. The phalanxhas a relatively small mid-body diameter suggesting some level of disuse atrophy. The only reactive alteration to the M5 is a more robust M4-M5 inter-metatarsal facet and crushing damage to the lateral distal joint surface.

The inter-cuneiform bone remodeling parallels the damage to the corresponding articulation with the proximal metatarsals. The only damage to the medial cuneiform is at the articulation with the intermediate cuneiform. The intermediate cuneiform, in turn, shows reactive change to the articular surface with M2. There is no tarsometatarsal joint damage to the lateral cuneiform, which is very likely reflective of the minimally functional third metatarsal.

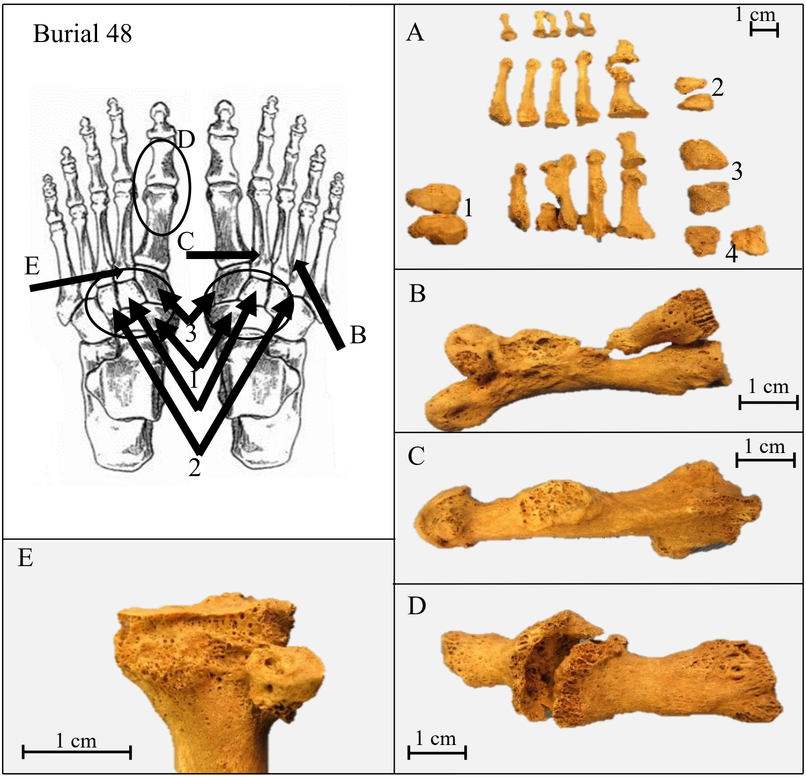

Figure 5: Examples from Burial 48 A) preserved tarsals, metatarsals, and phalanges from the right and left feet, B) pseudarthrosis, fusion, and periosteal reactive change to the right third and fourth metatarsals, C) right second metatarsal with a pressure facet along medial surface, D) no area of unremodeled surface of the left distal M1 and articulating proximal phalange, E) small bone overgrowth on the proximal left M2.

The reactive change on the left hallux includes osteophytic remodeling of the proximal joint margin and a ten-millimeter difference in length compared to the body of the right M1. The distal M1 joint and the articulating proximal first phalanxdo not exhibit any area of unremodeled surface (Figure 5, Burial 48d). Indeed, the articulation suggests the hallux may have been unable to plantar flex. Like the right M1, there is a pressure facet on the mediodorsal joint surface where it articulates with M2. The M2 has a bone spur (Figure 5, Burial 48e) where it articulates with M1 and sustained complete distal joint destruction (e.g., lipping, osteoarthrotic pitting).

M3 also exhibits total distal joint destruction. The proximal joint surface is without any reactive change as is the proximal surface of M4. The distal joint of M4 also exhibits no reactive change. However, there is osteophytic remodeling along the proximal intermetatarsal surface of M4-M5 with a small area of eburnation evident where it is in contact with a shortened M5 exhibiting reactive periostotic remodeling along the entire length of the body. The three intact proximal phalanges exhibit reactive change at the metatarsophalangeal but not the interphalangeal joint. However, all three-exhibit destruction of the phalangeal bodies suggesting some level of functional atrophy of the toes. A much remodeled and distorted proximal phalanxmay indicate an amputation at the medial phalange. Not only is there no distal joint, but the body has atrophied to a point. The osteoarthrotic change of pitting on the joint surfaces of the tarsals occurs on the articulating joint surfaces of the cuboid with the lateral cuneiform and the lateral cuneiform with the intermediate cuneiform. There is some osteophytic lipping at the juncture of the intermediate and lateral cuneiform with the navicular and along the intermediate cuneiform and M2 and lateral cuneiform and M3 margins. The assessment of the collective damage to the feet of Burial 48 suggests there was vertical load metatarsal stress (i.e., “march)” fractures (Giuliani et al. 2011; Hinz et al. 2008; Stokes et al. 1979).

Discussion

Skeletal remains offer a wealth of information when attempting to answer questions about the overall condition of life, health, and subsistence of members of extinct communities (Larsen 2015; Steckel 2004). The Schroeder Mounds skeletal sample tentatively dates to the subsistence/settlement transition from semi-sedentary horticulturalism (i.e., cultivating native plants [e.g., maygrass, marsh elder]) to village-based maize agriculture (Emerson et al. 2000; Mosher et al. 2015; Riggle 1981). Indeed, preliminary research suggests that the Schroeder Mounds community cultivated maize (Lacy and Smith 2013). However, Late Woodland subsistence and settlement patterns in west-central Illinois are only generally understood (Collins 1997; Benn and Green 2000; Emerson et al. 2000; Mosher et al. 2015; Steckel 2003, 2004) and there is little activity level or sample frequency comparative information available regarding trauma to the foot/ankle. Only tentative conclusions are possible at this time.

In general, males of the Late Woodland period are thought to have participated in more physically exertive activities relative to females (Agnew and Justus 2014; Claassen 2002; Claassen and Joyce 1997; Bridges et al. 2000). Males are argued to engage in distance-dependent activities related to trade (Emerson et al. 2000; Bridges et al. 2000; Steckel 2004) or subsistence (i.e., hunting). After the introduction of maize agriculture, it is believed that women focused more on the production of trade goods, child rearing, and other activities focused near the residential area (Claassen 2002; Claassen and Joyce 1997; Bendremer 1999). Comparative data suggests that males often show a greater prevalence of injuries than females, however at the sites of

1Pi61 and Koger Island, females show a higher instance of overall injuries (Bridges et al. 2000). Although sampling error should be considered, the cases of foot trauma from the Schroeder Mounds sample between males and females have a similar injury pattern. This could suggest similar activities, mobility or vulnerabilities that are specific to Illinois. The possible scenarios that resulted in the suite of injuries seen in the Schroeder sample may frame questions about their subsistence/settlement patterns.

The comparative sites of Perry and 1Pi61 have the greatest prevalence of fractures to the lower limbs. It is believed that the Archaic hunter-gatherers at the Perry site may have been prone to more accidental trauma. The sex ratio between males and females are highest at this site, with three times as many injuries sustained by males (Bridges et al. 2000). An explanation could be that hunting activities would lead to higher frequencies of accidental trauma at the Perry site. Koger Island shows the highest frequency of fractures to the fibula, followed by the femur, and then the foot/ankle (Bridges et al. 2000). The Late Woodland 1Pi61 site has the most fractures in the foot/ankle region, followed by the fibula. The Mississippian site of Moundville, shows the least amount of lower limb injuries compared to the other sites (11/564). The overall injury rate, follows the mortality rates for the comparative sites, with Koger Island as the highest, followed by 1Pi61, the Perry site, and Moundville (Bridges et al. 2000). It is believed that these instances of trauma were most likely caused by accidents, although it is discussed that reasons behind these injuries are largely speculated (Bridges et al. 2000).

Lisfranc Injuries, "March" Fractures, and Pilon Fractures

Burials #2, #26, and #46 exhibited injuries to the midfoot that are clinically identified as Lisfranc injuries. The Lisfranc joint complex consists of the articulations of four tarsal bones (medial, intermediate, and lateral cuneiforms, and the cuboid) with one or more of four metatarsals (M2-M5) (Castro et al. 2010; Gotha et al. 2013; Gupta et al. 2008). The articulations are critical to the stability of the foot (Borroughs et al. 1998; Gotha et al. 2013; Ly and Coetzee 2006). The joint is weakest along the dorsal aspect and between the first and second metatarsal bases as there is no intermetatarsal interosseous ligament in this area (Desmond and Chou 2006). A severe twisting motion causes an abduction of the forefoot and can lead to a fracture or dislocation at the base of the second metatarsal (Desmond and Chou 2006). The epidemiology of Lisfranc injuries in clinical contexts suggests that footwear plays a role in the vulnerability to tarsometatarsal injuries. Specifically, incidence increases with softer, more flexible footwear (Clanton et al. 1986). Injuries along this joint complex are considered clinically rare (.02% of all fractures), complex, and often misdiagnosed (Borroughs et al. 1998; Desmond and Chou 2006). The clinical data also suggests that one-third of Lisfranc injuries are the result of low energy trauma (e.g., falls while standing). The remaining two-thirds of these injuries are a result of high-energy trauma that is clinically observed in falls from a height (likely the cause for Burial #46) or is seen in certain sports (Castro et al. 2010; Gotha et al., 2013). The left foot of Burial #46 shows extensive remodeling of the proximal M1 through medial M4. There is osteophytic compressive damage to the joint surfaces of M2-M4, as well as corresponding osteoarthrotic damage to the tarsometatarsal joints and the dorsal joint perimeters of the intermediate and lateral cuneiforms. There is no damage to the medial cuneiform. The proximal M1 shows evidence of some lipping. This damage is consistent with a Lisfranc injury to the midfoot. Lisfranc fractures annually occur in 4% of collegiate football players (DeOrio et al. 2009). Indeed, midfoot sprains are the second most common athletic foot injury, behind metatarsophalangeal joint injuries. (DeOrio et al. 2009; Eleftheriou and Rosenfeld 2013). Besides football, the most common sports where athletes sustain Lisfranc injuries are running, horseback riding, and soccer. When an individual sustains a Lisfranc fracture after falling from a height, many of the joints and bones in the foot are often involved (Castro et al. 2010; Gotha et al. 2013). These, more serious, Lisfranc injuries can later result in arthritis and flatfeet. Injuries at this joint complex do not heal well without medical intervention (Borroughs et al. 1998; DeOrio et al. 2009; Foster and Foster 1976; Gissane 1951; Gotha et al. 2013).

Fractures to the shaft of metatarsals such as those exhibited by Burial #48 are referred to as “march” fractures as they are common to individuals engaged in long-distances walking, such as soldiers (Giuliani et al. 2011; Hinz et al. 2008; Stokes et al. 1979). “March” fractures occur from recurrent stress to the shafts of the metatarsals (Guilinani et al. 2011). Repetitive action, such as marching, results in microtrauma to the metatarsals, which occurs over a period of days, weeks, or months (Guiliani et al. 2011; Hinz et al. 2008; Stokes et al. 1979). The result is from prolonged and repeated foot strain, to the point beyond the capacity for the bone to bear stress (Guiliani et al. 2001; Krause 1942). The suggestion that extensive foot travel predisposes to “march” fractures suggests the subsistence strategy of the Schroeder Mounds community, although engaged in maize cultivation, was still very mobile.

Tibial Pilon Fractures, like that seen in Burial #46, are considered severe injuries that affect the distal articular surface of the tibia. Pilon fractures involve the dome of the distal tibial articular surface and extend to the adjacent metaphysis. The co-associating fibula may or may not be intact as a result of this injury (Mandracchia et al. 1999). These fractures are usually the result of a high-energy axial impact due to the talus being driven into the tibial plafond, and are also associated with soft-tissue injuries (Muller and Nerlich 2010). Based on their severity, fractures to the tibial pilon are difficult to manage. The result can be an impaction of the weight-bearing surface of the distal tibia, making it difficult for those affected to be mobile (Mast et al. 1988; Muller and Nerlich 2010). High-energy impacts to the distal tibia, suggest that individuals at Schroeder Mounds could have been partaking in some hazardous behaviors (i.e., jumping from a height).

Pathological M4

The shortened M4 shafts of Burial #115 are consistent with a diagnosis of brachymetatarsia (Ferrandez et al. 1993; Handelman et al. 1986; Robinson and Ouzounian, 1998; Schimizzi and Brage 2005). As in the case of Burial #115, it most commonly affects the fourth metatarsal. Although it is likely a congenital condition, trauma may be a predisposing or a trigger mechanism (Schimizzi and Brage 2005) and should be included in the discussion here. Although it is clinically rare, it is evidently not absent in pre-Columbian Illinois. There are two cases from the Late Mississippian Norris Farms site (Santure 1990) and cases from Late Woodland/Early Mississippian site samples from Schild and Morton (Spencer 2014). It is unknown whether the pre-Columbian prevalence of brachymetatarsia is higher than the clinical occurrence.

Conclusion

The Schroeder Mounds adults exhibit a 13.5% frequency of foot/ankle trauma. Thirty-seven adults are too small a sample to assess any subsistence/settlement relevance to the frequency, particularly with no comparative bioarcheological data from Illinois. The absence of distal pedal phalanges makes it difficult to assess stubbing injuries, however, the pattern of Lisfranc traumatic injury and "march" fractures suggests mobility in a maize agricultural community. The occurrence of foot/ankle related trauma at Schroeder Mounds suggests that footwear, if present, did little to buffer injury to otherwise rarely injured tarsometatarsal joints. Further research should be done to understand the importance footwear plays in protecting the foot from injury. More information is certainly needed from other pre-Columbian Illinois osteological samples to help contextualize the Schroeder Mounds activity patterns. This study has aided in further understanding the cultural and environmental background of the forager-farmers at the Schroeder Mounds site.

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